

Specification

MAGNETIC HEAD P1 MAGNETIC POLE NOTCHING WITH REDUCED POLYMER DEPOSITION

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to methods for fabricating magnetic heads, and more particularly to methods for notching the P1 magnetic pole of such magnetic heads.

Description of the Prior Art

One approach to increasing the areal data storage density of magnetic disks is to narrow the width of the data tracks written on the disks, such that more tracks per inch can be written, and therefore more data stored on the disk in a given area. Generally, the width of the base of the P2 magnetic pole tip determines the width of the data track; however, it is also necessary to provide some spacing between adjacent tracks, and the spacing required between data tracks is a function of the strength of the fringing magnetic fields that are created by the magnetic head. In some prior art magnetic heads, the fringing fields can be strong enough to affect data in neighboring data tracks, and the width of a fringing magnetic field can be a significant portion of a data track itself. Therefore, it is desirable to minimize the fringing fields generated by magnetic heads, such that adjacent data tracks can be written more closely together, and the areal data storage density on the disk thereby increased.

One of the fabrication methods that has been undertaken in the prior art to reduce the fringing fields is to notch the P1 magnetic pole, as is known to those skilled in the art. Such P1

5 pole notching can substantially reduce the fringing magnetic fields generated by the magnetic head, and can thereby increase the areal data storage density on the disk. The standard P1 notching process of the prior art utilizes the previously fabricated P2 pole tip as an etching mask element in the notching process, and the process includes first etching through the write gap layer, typically alumina (Al_2O_3), and then etching into the P1 pole layer (typically ~~Permalloy~~ ^{PERMALLOY}, a NiFe compound). A problem that initially exists in the prior art P1 notching process is that an argon ion beam was utilized to etch the P1 pole notches, and the alumina write gap layer is significantly more resistant to etching by the argon ion beam than the NiFe material of the P2 pole tip and the P1 layer. Therefore, where an argon ion beam was used in the prior art to conduct the P1 notching step, significant portions of the P2 pole tip were etched away while the beam more slowly etched through the alumina write gap layer. Thereafter, further portions of the P2 pole tip were etched away while the P1 pole was subsequently notched by the ion beam. As a result, the earlier prior art P1 pole notching process required the initial fabrication of a rather thick P2 pole tip, such that a properly sized P2 pole tip remained following the etching in the P1 notching step utilizing an argon ion beam.

A prior art improvement in P1 notching involves the initial utilization of a first etchant gas species accelerates the etching of the alumina write gap layer and slows down the etching of the NiFe P2 pole tip material. Such a prior art etchant gas is CHF_3 , and following the use of CHF_3 in the etching process to etch through the alumina write gap layer, the etchant gas was changed to argon to notch the P1 pole. As a result, a much smaller portion of the P2 pole tip was etched away during the P1 notching step than was previously the case. This prior art also teaches that a decrease of the NiFe etch rate in CHF_3 milling occurs due to the formation of a polymer layer on the surface of the NiFe pole.

A problem that has arisen with the use of CHF_3 in the etching process is that it creates excessive polymer deposition. The polymer deposition can cause product contamination and results in the need for frequent cleaning and maintenance of the tooling hardware. Such polymers are apparently created in chemical reactions associated with the ionization of the CHF_3 etchant gas, creating a significant problem in the utilization of CHF_3 for P1 notching. The present invention avoids the excessive polymer deposition problems of CHF_3 while maintaining the benefits of the two-step P1 pole notching process. Specifically, the present invention is a P1 notching process utilizing C_2F_6 as a preferred substitute for CHF_3 .

SUMMARY OF THE INVENTION

The present invention includes a two-step etching process for notching the P1 pole of the write head element of a magnetic head. In a first step, the preferred embodiment utilizes a combination of C_2F_6 and argon gases (designated as $\text{C}_2\text{F}_6/\text{Ar}$) as the etchant gas to preferentially etch portions of the alumina write gap layer. Thereafter, in the second step, argon is used as the etchant gas to preferentially etch the P1 pole material. The $\text{C}_2\text{F}_6/\text{Ar}$ etchant gas preferably includes C_2F_6 gas in a concentration range of from 50% to 90%, with a preferred concentration range being from 70% to 80%. The etching of the alumina write gap layer is preferably conducted with a first etchant ion beam angle of from 5° to 30° , and a second etchant ion beam angle of from 65° to 85° .

It is an advantage of the P1 notching process of the present invention that contamination of magnetic head during a P1 notching step is reduced.

It is another advantage of the P1 notching process of the present invention that it avoids frequent cleaning and maintenance of the tooling hardware.

It is a further advantage of the present invention that a two-step P1 notching process has been developed that rapidly etches the write gap layer in a first step and rapidly etches the P1 layer in a second step.

It is yet another advantage of the present invention that a magnetic head is reliably manufactured that has reduced fringing magnetic fields.

It is yet a further advantage of the present invention that a magnetic head has been developed having a right head element that produces reduced fringing magnetic fields, such that the areal data storage density on hard disks can be increased.

These and other features and other advantages of the present invention will no doubt become apparent to those skilled in the art on reading the following detailed description which makes reference to the several figures of the drawing.

IN THE DRAWINGS

Fig. 1 is a side cross-sectional view of a fabrication step of a prior art magnetic head;

Fig. 2 is a side cross-sectional view of a prior art P1 notching step of the magnetic head depicted in Fig. 1;

Fig. 3 is a side cross-section view of a first etching step of the P1 pole notching process of the present invention; and

Fig. 4 is a side cross-sectional view of a second etching step of the P1 pole notching process of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a side cross-sectional view of a prior art magnetic head taken during the fabrication of the write head elements of the head. As is well known to those skilled in the art, the magnetic head 10 includes a P1 pole 14 having a write gap layer 18 deposited thereon, and having a P2 pole tip 22 deposited onto the write gap layer. Typically, the write gap layer is comprised of alumina (Al_2O_3) and the P1 pole and P2 pole tip are composed of a NiFe compound such as ~~Permalloy~~ ^{PERMALLOY} (NiFe 80/20).

Fig. 2 is a side cross-sectional view depicting a typical prior art P1 notching step. As depicted therein, an ion beam 40 has been directed through a suitable photoresist mask 44 to etch through portions of the write gap layer 18 immediately next to the P2 pole tip 22, and to further create notches 46 within the P1 layer 14. As indicated above, an initial problem associated with the P1 notching process was that significant portions 48 of the P2 pole tip (shown in phantom) were etched away while the argon etchant gas more slowly etched through the alumina write gap layer 18. Subsequently, a two step etching process was developed wherein CHF_3/Ar was first utilized as an etchant gas to create etchant species that preferentially etched the alumina over the NiFe pole tip material. This prior art two-step etching process results in less etching of the P2 pole tip during the P1 notching process, however it has the undesirable problem of creating excessive organic polymer compounds that contaminate the wafer.

The present invention involves the use of C_2F_6 gas in place of the CHF_3 as a first etchant gas in a two-step P1 notching process. As depicted in Fig. 3, in using a combination of C_2F_6 and argon (designated herein as $\text{C}_2\text{F}_6/\text{Ar}$) as a first etchant gas, etchant species 60 are created that selectively etch the alumina write gap layer preferentially over the NiFe P2 pole tip material. As described in detail hereinbelow, the ion beam of $\text{C}_2\text{F}_6/\text{Ar}$ etchant gas is preferably directed at a

relatively steep angle 60 and subsequently at a relatively shallow angle 64. After the alumina write gap layer has been etched using C_2F_6/Ar to form notches 66 through the alumina layer 18, argon gas is substituted for the C_2F_6/Ar in order to form etchant species that are also directed at a relatively steep angle 80 and subsequently at a relatively shallow angle 82 to form notches 84 in the P1 pole 14 as is depicted in Fig. 4.

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Significantly, the use of C_2F_6 as an etchant gas creates fewer organic polymer contaminants than are seen with the prior art CHF_3 etchant gas. Thus, reduced cleaning and maintenance of tooling hardware is required. Additionally, it has been unexpectedly found that exposing NiFe to fluorine ion containing species, such as those generated in the C_2F_6 gas chemistry results in the formation of a beneficial Ni fluoride compound thin film layer on the surface of the P2 pole tip. Specifically, the Ni fluoride thin film 88 on the surface of the P2 pole tip apparently provides a protective layer that is more slowly etched by the argon etchant species than an unprotected NiFe P2 pole tip. This is in contrast to that which is found in the prior art CHF_3 etchant gas process, in which a polymer layer is formed to slow down the NiFe etching. Thus, the use of the C_2F_6 etchant gas also provides some protection for the P2 pole tip during the second step of the P1 layer notching with the argon etchant gas species.

As indicated above, the method for fabricating the notched P1 pole magnetic head 50 of the present invention involves two ion beam etching steps, the write gap layer etching step and the P1 pole etching step. For both steps, the ion beam voltage should be in the 600-900 volts range, with a more preferred range of 650-750 volts. The ion beam current should be in the 600-1200 mA range, with a more preferred range of 900-1100 mA.

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There are two objectives in the write gap layer etching step; the first objective is to remove the write gap layer material, and the second objective is to remove any write gap layer

redeposition material that is accumulated on the sidewalls of the P2 pole tip. As shown in Fig. 3, for write gap layer material removal, the incident angle i from the normal to the substrate surface of the C_2F_6/Ar beam 60 is selected to be greater than the P2 pole slanting angle s , from the normal to the substrate surface. As is known to those skilled in the art, the angle s results from the P2 pole plating process conditions. Thus, where angle i is greater than angle s the shadowing of the P2 pole base by the P2 pole top is avoided. For example, if the slanting angle s is 5° , the incident angle i should be 10° or greater. In general, the angle i should be in the range of $5 - 30^\circ$, with a more preferred range of $10-20^\circ$. For removal of redeposition material from the sidewalls of the P2 pole tip structure, the incident angle i of the C_2F_6/Ar beam 64 is chosen to be in the range of $65-80^\circ$, with a preferred range of $70-75^\circ$. Because of the good etching selectivity of Al_2O_3 over NiFe, this P2 pole tip sidewall cleaning step will not alter the P2 pole tip track width even if an aggressive overetch is applied.

The write gap layer etching step can be completed with one low angle (for example 15°) ion milling step to etch through the write gap layer material, followed by one high angle milling step (for example 70°) to remove the redeposition material from the P2 pole tip sidewalls. Alternatively, the low angle milling step and high angle milling step can be alternated sequentially until the write gap layer material is completely removed and the P2 pole tip sidewalls are free of redeposition material.

As indicated above, the gas mixture for the write gap layer etching step utilizes an etchant gas composed of C_2F_6 and Ar. The concentration of C_2F_6 in the gas mixture may be in the range of $50-90\%$, with a more preferred C_2F_6 concentration in range of $70-80\%$. In this concentration range, a stable etching condition can be maintained while a good $Al_2O_3/NiFe$ etch rate ratio can

be achieved. For example, at approximately 75% C_2F_6 and a 10° ion beam incident angle, the $Al_2O_3/NiFe$ etch rate ratio is approximately 8:1.

Following the write gap layer etching step, the etchant gas is switched to Ar for the P1 pole material etching step to complete the P1 pole notching. For this P1 pole material etching step, again there are two objectives. The first objective is to remove enough P1 pole material to produce the desired notching, and the second objective is to remove any P1 pole redeposition material that accumulates on the P2 pole tip sidewalls. Compared to C_2F_6 , the Ar ions etch the NiFe of the P1 pole at a much faster rate. As a result, the P2 pole tip track width may be altered during the redeposition material cleaning process. Therefore, it is desirable to minimize the amount of redeposition material produced in the P1 pole etching step, because where there is less redeposition material on the P2 pole tip sidewalls, a shorter redeposition cleaning step is needed and the likelihood of altering the P2 pole tip track width is reduced. The incident angle j (from the normal to the substrate surface) for P1 pole material removal is thus chosen to be in the $15-50^\circ$ range, with a preferred range of $30-45^\circ$. For the P2 pole tip sidewall cleaning process, the incident angle j is chosen to be in the range of $65-80^\circ$, with a more preferred range of $70-75^\circ$. The P1 pole material etching step can be completed with one low angle (for example 30°) milling step to etch into the P1 pole material, followed by one high angle milling step (for example 70°) to remove the P1 pole redeposition material on the P2 pole tip sidewall. Alternatively, the low angle milling step and the high angle milling step can be alternated sequentially until a desired P1 pole notching depth is achieved and the P2 pole tip sidewall is free of redeposition material.

While the present invention has been shown and described with regard to certain preferred embodiments, it is to be understood that those skilled in the art will no doubt develop

certain alterations and modifications thereto. It is therefore intended that the following claims cover all such alterations and modifications that nevertheless include the true spirit and scope of the present invention.

What is claimed is:

1. A method of determining a value of a function of a variable, the method comprising: receiving a value of the variable; and determining the value of the function of the variable based on the received value of the variable.